Evaluation of electrostatic sprayers and foggers for the application of disinfectants in the era of SARS-CoV-2

EPA ORD Covid-19 Research Webinar

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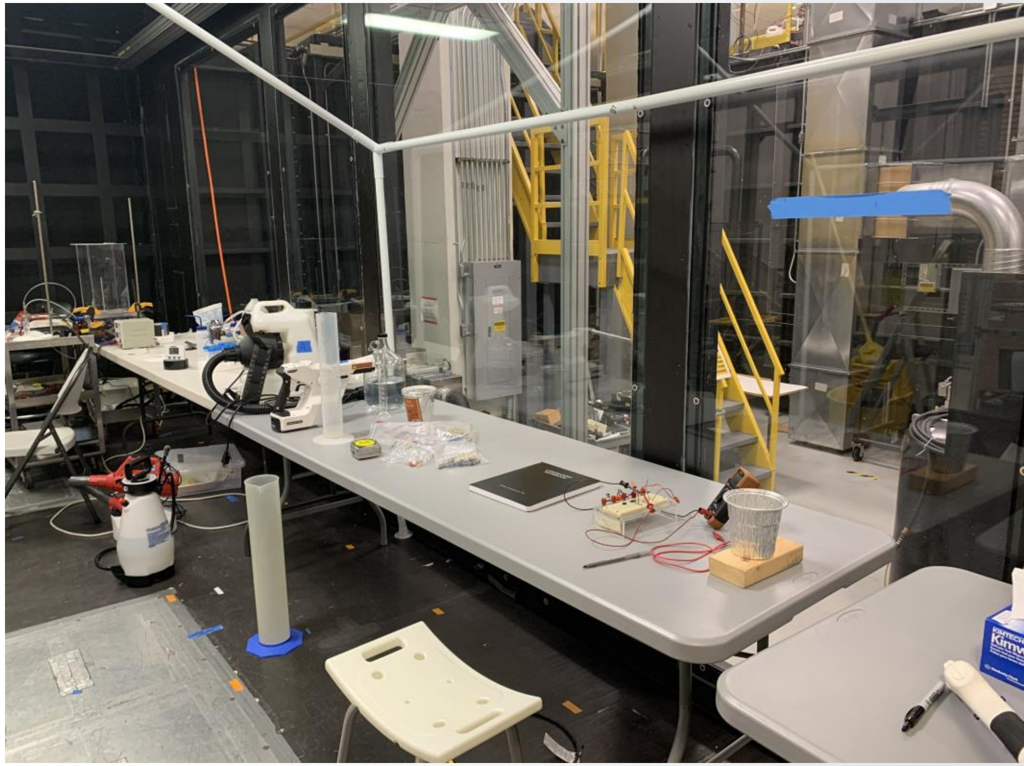
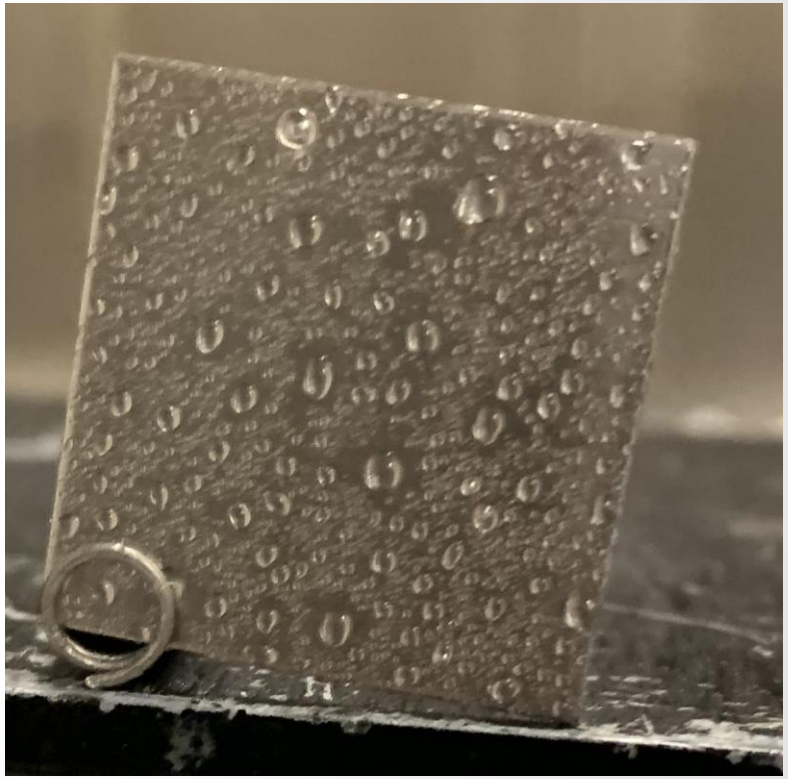
Outline of presentation

- Background
- Droplet size distribution of sprayers and foggers
- Loss of disinfectant active ingredient when spraying
- Spray droplet charge
- Deposition and related tests
  - Recommended amount of disinfectant to apply to surfaces
  - Wetness tests
  - Black light tests
  - Wetness sensor tests
- Disinfection efficacy tests



Background

- COVID-19 primarily caused by airborne transmission of the SARS-CoV-2 virus, but cleaning and disinfection of surfaces is recommended by CDC
- Use of electrostatic sprayers (ESS) and foggers to rapidly apply disinfectants over large areas or complex surfaces increased substantially with the COVID-19 outbreak
- ESS impart an electrostatic charge to the disinfectant spray droplets with the goal of improving deposition of the droplets onto surfaces

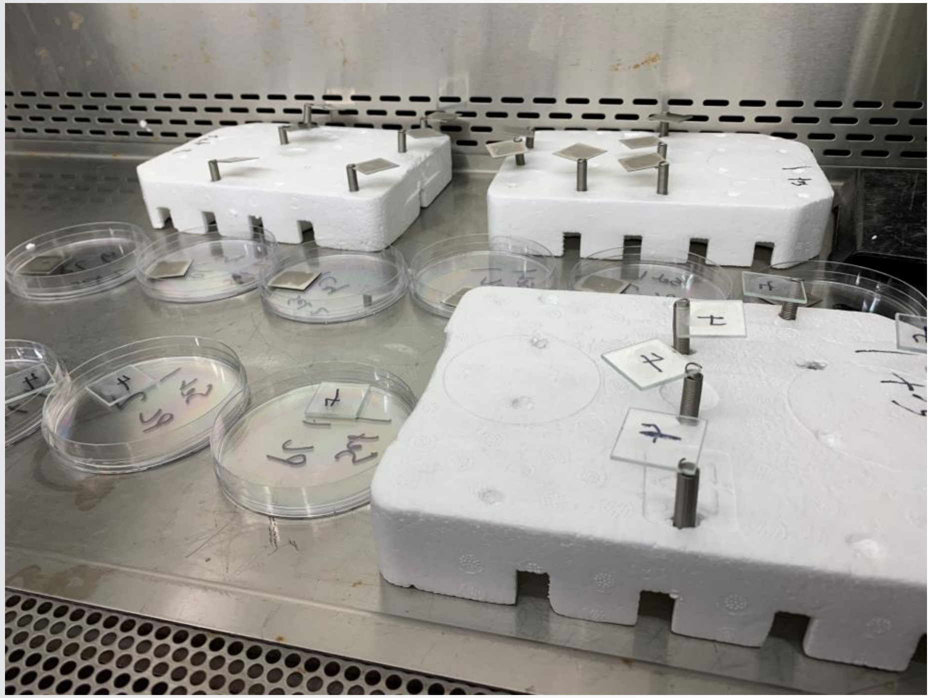


Research objective

- Evaluate some of the underlying operating parameters for several ESS and foggers to elucidate any issues related to their application of disinfectants to surfaces

ESS parameters evaluated

Some parameters may impact disinfectant ability to inactivate virus on surfaces



- The electrostatic charge imparted to the spray
  - May affect ability to deposit onto surfaces, including surfaces not in the direct path of the spray
- The amount of disinfectant to apply to a surface
  - Must remain wet for required contact time of disinfectant
- Loss of disinfectant’s active ingredient to the air
  - Any loss of active ingredient to air will diminish concentration of the active ingredient on the surface, thus potentially reducing disinfection efficacy

ESS only as effective as the disinfectant being sprayed

Spraying of disinfectants may create exposure concerns

- Active ingredient of the disinfectant may be inhaled as vapor/gas or via droplets
- Droplet size distribution (DSD) of the spray was measured
  - Smaller droplets more readily inhaled
  - EPA Office of Pesticide Programs guidance indicates volumetric median diameter (VMD) should be ≥ 40 microns

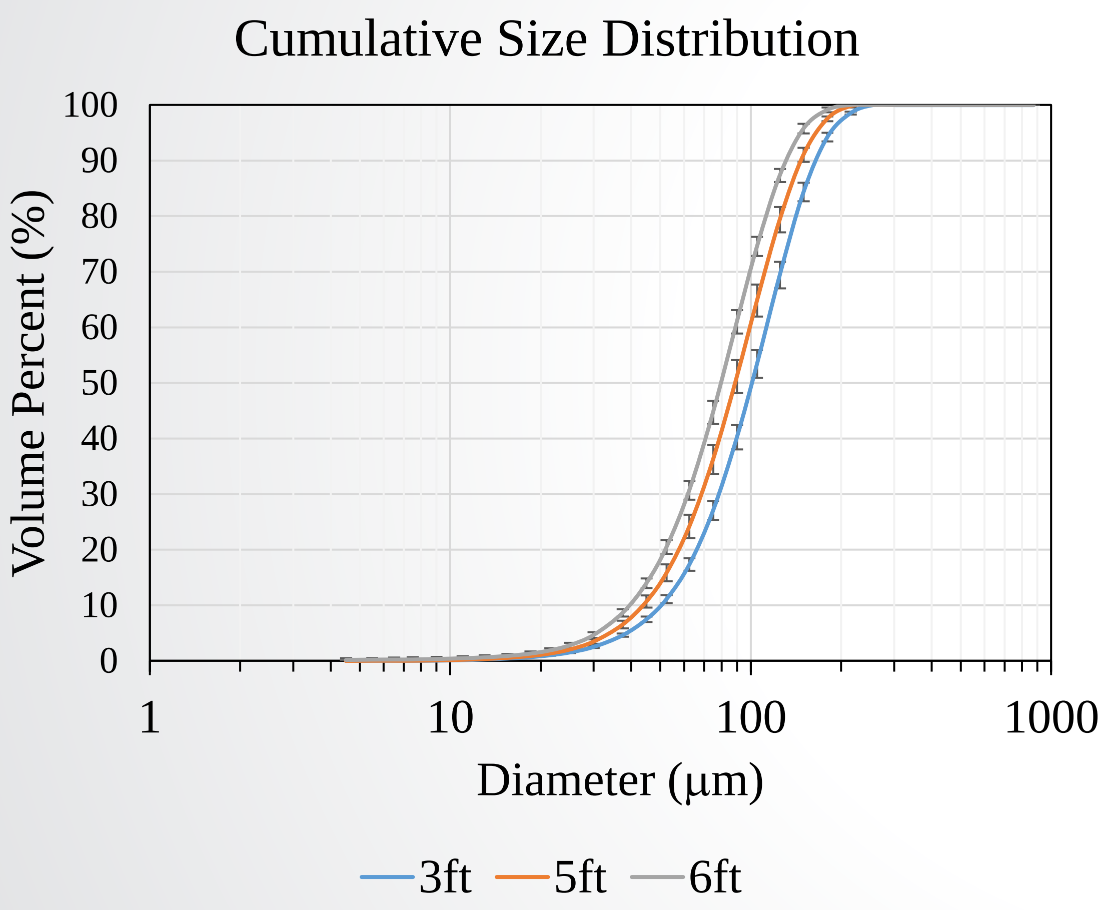
Sprayers and foggers tested

	Manufacturer or distributor	Type of device	Source of electrical power	Notes
PX200ES handheld (HH)	Earthsafe Chemical Alternatives, Braintree, MA	ESS	Battery	This model has the ability to turn on and off the electrostatics. The Li ion battery for this device was later recalled.
PX300ES backpack	Earthsafe Chemical Alternatives, Braintree, MA	ESS	Battery	This sprayer came with a 40-micron (red) and 80-micron (green) nozzle. The Li ion battery for this device was later recalled.
SC-ET	Electrostatic Spraying Systems, Watkinsville, GA	ESS	Cord plug-in	Purchased in ~ 2015 and used in several US EPA studies over the years, prior to this study. All the other devices evaluated were newly purchased for this study.
EM360 HH	Emist, Fort Worth, TX	ESS	Battery	
R40	360 Sterile, Burnaby, BC, CA	ESS	Battery	Lithium ion battery failed and was later replaced
Total 360	ByoPlanet, for Clorox, Oakland, CA	ESS	Cord plug-in	
Professional Sprayer 2-gallon R20S16	Husqvarna, Charlotte, NC	garden sprayer	None; hand pumped	
Airofog Flex ULV cold fogger U120	Airofog USA, Brooksville, FL	fogger	Cord plug-in	
Mist Duster KB-15002E 12L	Ipihsius via Amazon.com	fogger	Cord plug-in	This device was not tested for spray charge due to it becoming non-functioning during the droplet size distribution tests.

Droplet size distribution test methods

- Tests conducted in EPA's Aerosol Test Facility
- Laser diffraction instrument used to measure DSD
- Measured 5 times at each of several spray distances
- Measured with tap water, deionized water, and a few disinfectants

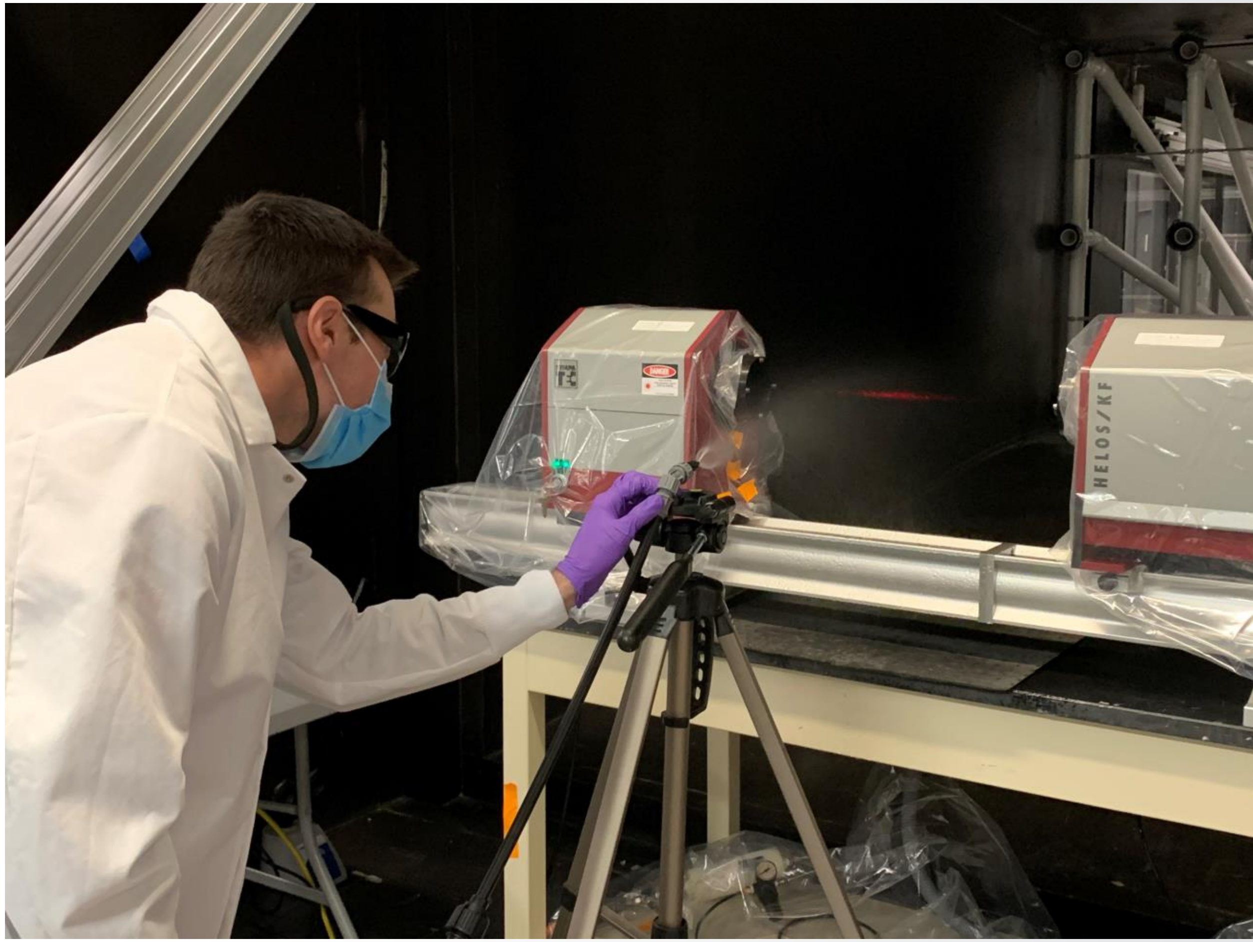
Droplet size distribution – example results



	Measured Flow rate (oz/min)	Recommended surface coverage (ounces of disinfectant per 1000 ft^2)	Volume median diameter range (microns)
PX200ES HH (on)	3.7	40	37-84
PX200ES HH (off)	3.8	NA	40-90
PX300ES backpack; red (40 micron) nozzle	3.9	28	40-65
PX300ES backpack; green (80 micron) nozzle	4.5	28	36-58
SC-ET	3.7	Recommends wetness test	28-31
Emist EM360 HH	1.9	2	83-105
360 Sterile R40	6.1	53	44-75
Clorox Total 360	4.1	14	46-53
Garden sprayer Husqvarna	17	NA	50-180
Airofog Flex ULV cold fogger	4.4	NA	43-46
iPihsius KB-1500 12L	11.2	NA	42-43

Droplet size distribution findings

- Most of the devices tested had VMD ≥ 40 microns
- Volume median diameter typically decreased with spray distance
- Device with adjustable nozzles size showed no difference in VMD
- Water source or use of disinfectant did not significantly impact DSD
- Most sprayers report droplet size, but not clear how they're determined



Loss of active ingredient test methods

- Tests conducted with a hydrogen peroxide- and dichlor-based disinfectant
- Used a handheld ESS
- Disinfectants sprayed and then droplets collected 3 feet away
- Active ingredient measured in air using electrochemical sensors
- Active ingredient of liquid disinfectants measured at 3 locations using titration techniques

Loss of active ingredient results

Results for spraying hydrogen-peroxide based disinfectant

Quantity or sample location	Hydrogen peroxide concentration (%) of disinfectant
As shown on label	8
Undiluted 11/8/20	6
Undiluted 12/22/20	5.7
1:32 dilution (label for SARS-CoV-2) – collected from reservoir	0.19
Diluted per label – collected at nozzle	0.19
Diluted per label – collected 3 feet away	0.20

Maximum vapor concentration of HP was 0.35 parts per million (Permissible Exposure Limit = 1 ppm)

Loss of active ingredient results

Results for spraying dichlor-based disinfectant

Quantity or sample location	Disinfectant free available chlorine Parts per million
Label (4 tablets per quart)	4306
As prepared stock solution	4347
Sampled from reservoir	4607-5028
Sampled from nozzle	4427-4667
Collected 3 feet away	1703*-4908

Maximum vapor concentration was 0.19 ppm chlorine gas (PEL= 0.5 ppm)

* Believed to be erroneous result

Droplet charge measurement methods

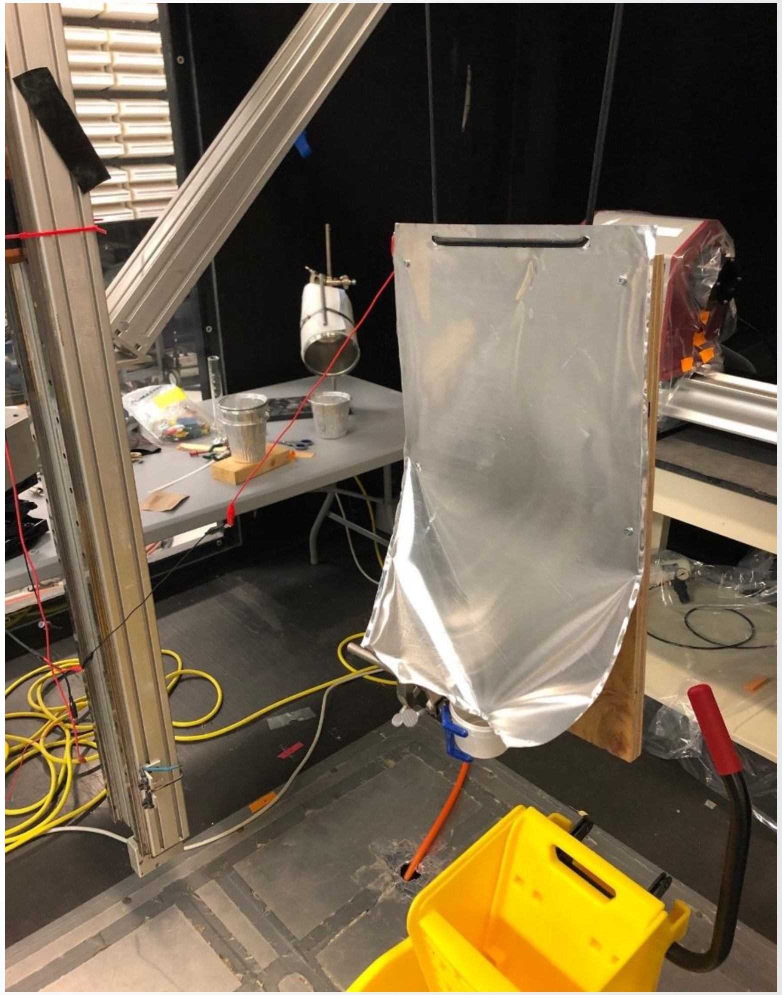
- No standard method to measure charge of spray
- We used method as described in literature
- Picoammeter used to measure current when sprayed on to an aluminum plate
- Results reported in charge/mass (milli-Coulombs/kg)
- Tests conducted with tap water and deionized water for all sprayers tested
- One sprayer tested with 3 different disinfectants

Droplet charge results

Sprayer	Average Charge to Mass Ratio, mC/kg DI water	Average Charge to Mass Ratio, mC/kg Tap water
PX200 ES on	0.109 ± 0.00	0.134 ± 0.03
PX200 ES off	0.005 ± 0.00	0.004 ± 0.00
PX300 red	0.049 ± 0.00	0.053 ± 0.00
PX300 green	0.045 ± 0.00	0.049 ± 0.00
Total 360	-6.05 ± 0.09	-5.74 ± 0.20
EM360	0.28 ± 0.00	0.29 ± 0.01
SC-ET	-3.56 ± 0.22	-3.28 ± 0.06
R40	0.00	0.00
Garden sprayer	0.00	0.00
Airofog	0.00	0.00
Total 360 HP	-1.79 ± 0.06	
Total 360 Quat	-1.08 ± 0.06	
Total 360 dichlor	-1.53 ± 0.00	

Droplet charge results summary

- Unclear what charge/mass is necessary to elicit benefits of electrostatic deposition of disinfectants on surfaces for virus disinfection
  - One reference suggests at least 0.1 mC/kg is needed (Gaunt, Hughes; 2003)
  - Four out of the six ESS tested for charge/mass produced sprays above that level
- Plug-in ESS showed highest charge and also negative charge
- No significant difference in charge when spraying DI vs tap water



How much disinfectant to apply to a unit area?

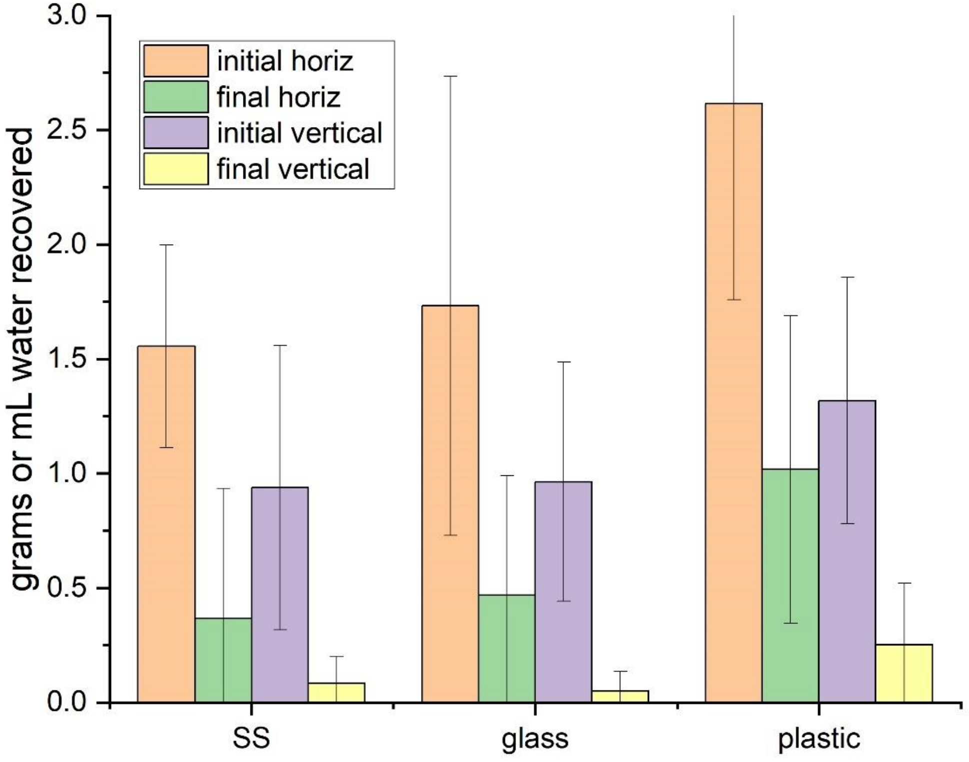
- Need to apply enough disinfectant so that surface remains wet for required contact time
- If surfaces are dry before contact time, need to reapply
- Some sprayer suppliers provided a recommended amount
  - For the devices tested and where info was available, ranged from 2-53 fluid ounces/1000 ft^2
  - One vendor recommended conducting a "wetness" test
  - One vendor recommended spraying disinfectant until droplets start to coalesce

Wetness test methods

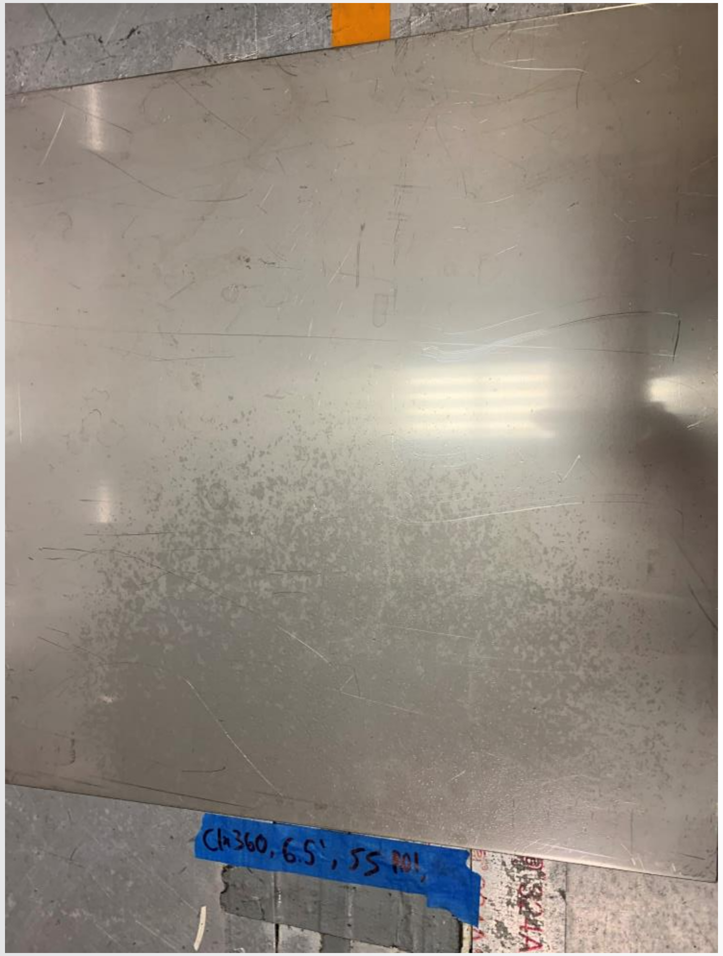
- Conducted to determine if a surface would remain wet at 10 minutes
- Used five different sprayers using water
- 14 X 14-inch coupons in vertical & horizontal position
- Sprayed coupons until droplets started to coalesce
- Coupons made from stainless steel, glass, and plastic
- Wipes used to recover water immediately after spraying, and after 10 minutes
  - Weighed to determine mass
- Temperature at 21 °C, 35% RH, air flow 1 m/s

Wetness tests results

- Coupons in horizontal position generally had higher initial deposition
- Amount of water initially deposited was in range recommended by ESS vendors
- Percent water loss somewhat higher for vertical coupons
- Plastic had the least amount of water loss



Wetness tests results continued

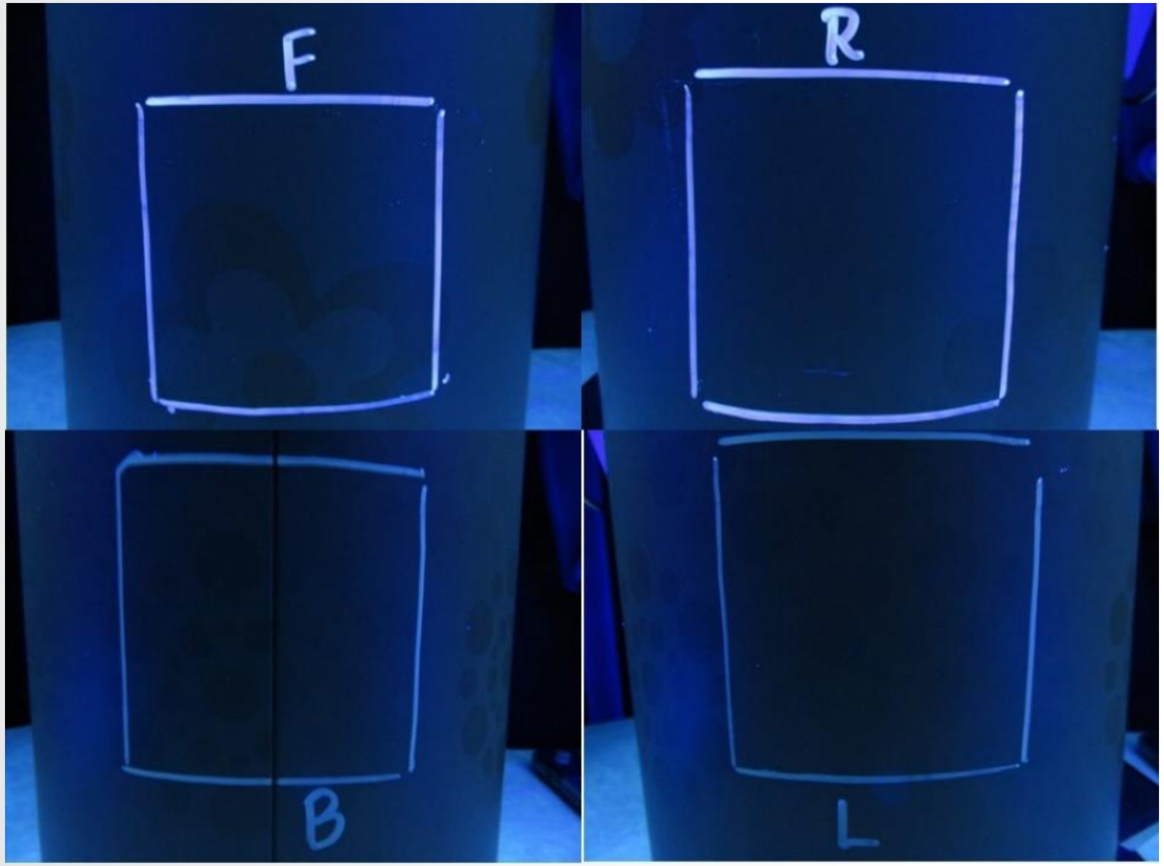


- About 13 % of coupons were completely dry after 10 minutes – based on weight
- Drying on the surface was uneven
  - Dry areas may not be effectively disinfected
  - gravimetric method reports coupon as still wet
- Many factors affect drying time
  - Initial deposition
  - Temperature, relative humidity, air flow
  - Material type and orientation
  - Active ingredient vapor pressure

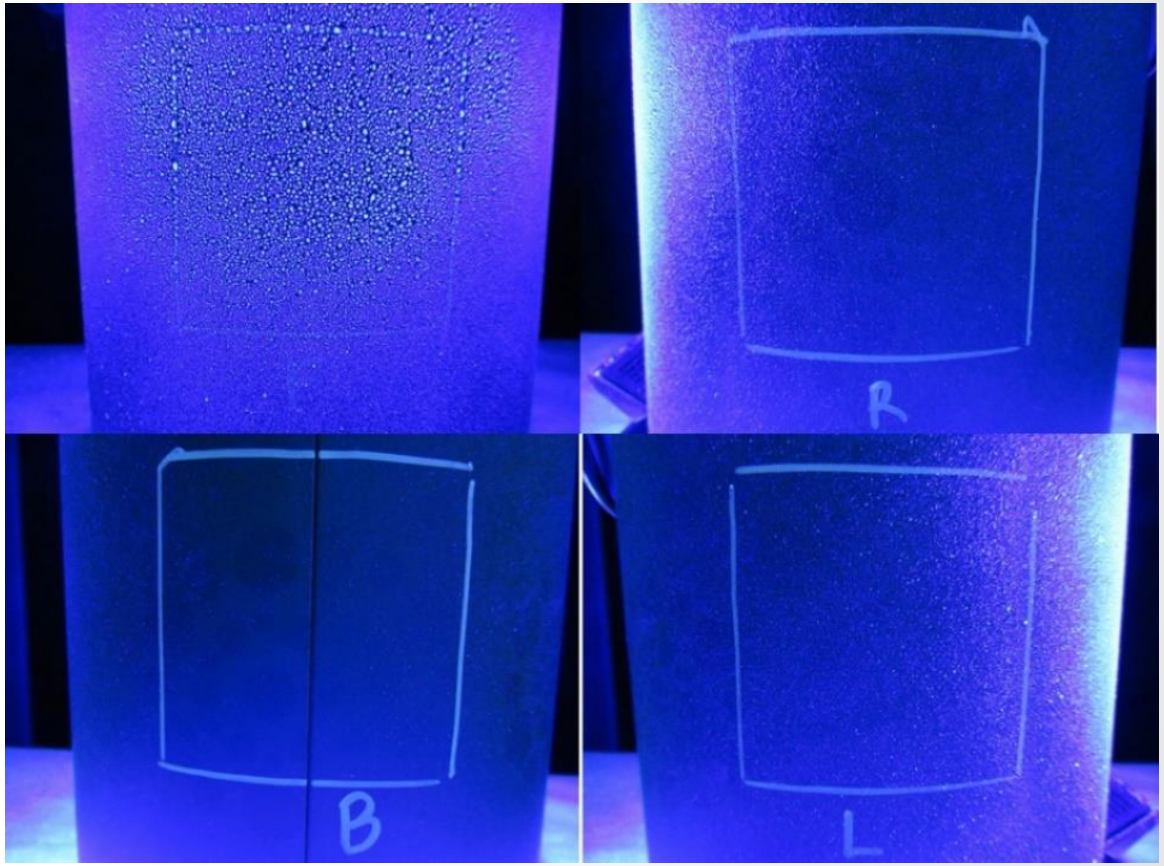
Black light test methods

- Tests conducted to visually assess wrap-around effect
  - Spray 8 inch dia black trash can with aqueous fluorescent dye
  - illuminate w black light, take photograph
- Photodocument front, left, right, back of can
  - whole can
  - 3 by 3-inch square
- Sprayed ~ 7-8 mL onto trash can or other objects, 1-4 second spray
  - step ladder, clip-on lamp, chair

Black light test results



Example positive controls



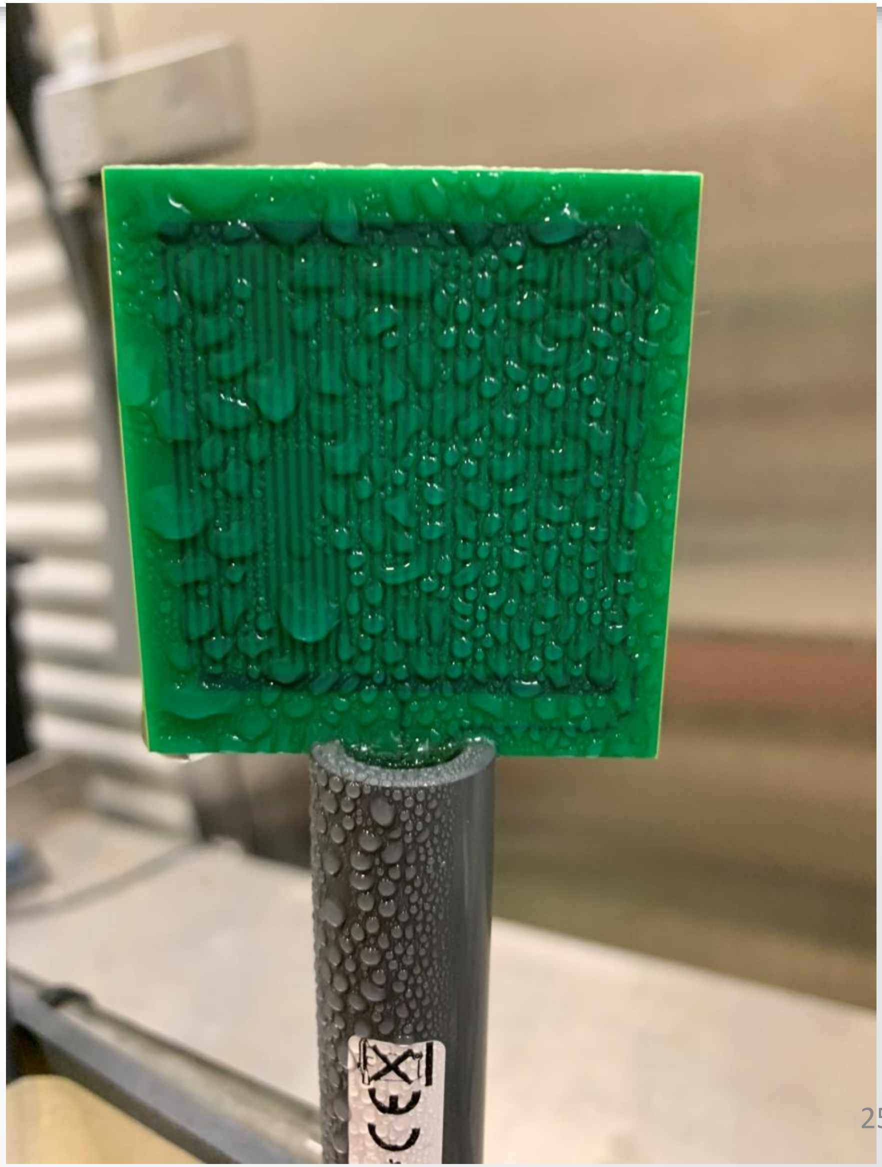
Example results for sprayed trash can

Black light test results continued

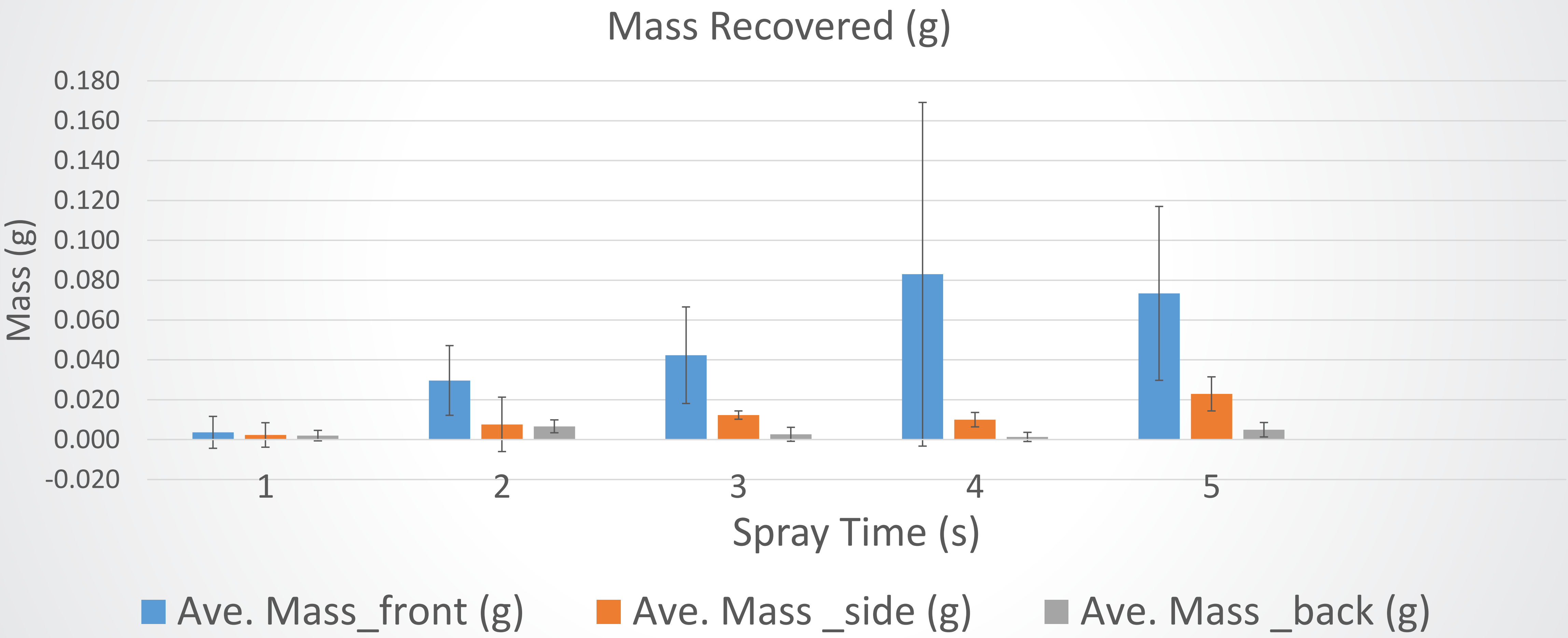
- Deposition results very similar for all ESS and foggers tested
- Wrap around effect not as pronounced as expected
- Small objects like lamp shade showed more of an effect

Wetness sensor test methods

- Leaf wetness sensors used to quantify deposition (as opposed to qualitative visual results)
- Sensor provides percent wet reading; we correlated to mass deposited
- Sensor placed directly facing ESS, turned to side (90 degrees), and turned completely around (180 degrees)
- Test conducted with ESS



Wetness sensor test results



R^2 = 0.94 correlation between mass recovered and sensor reading

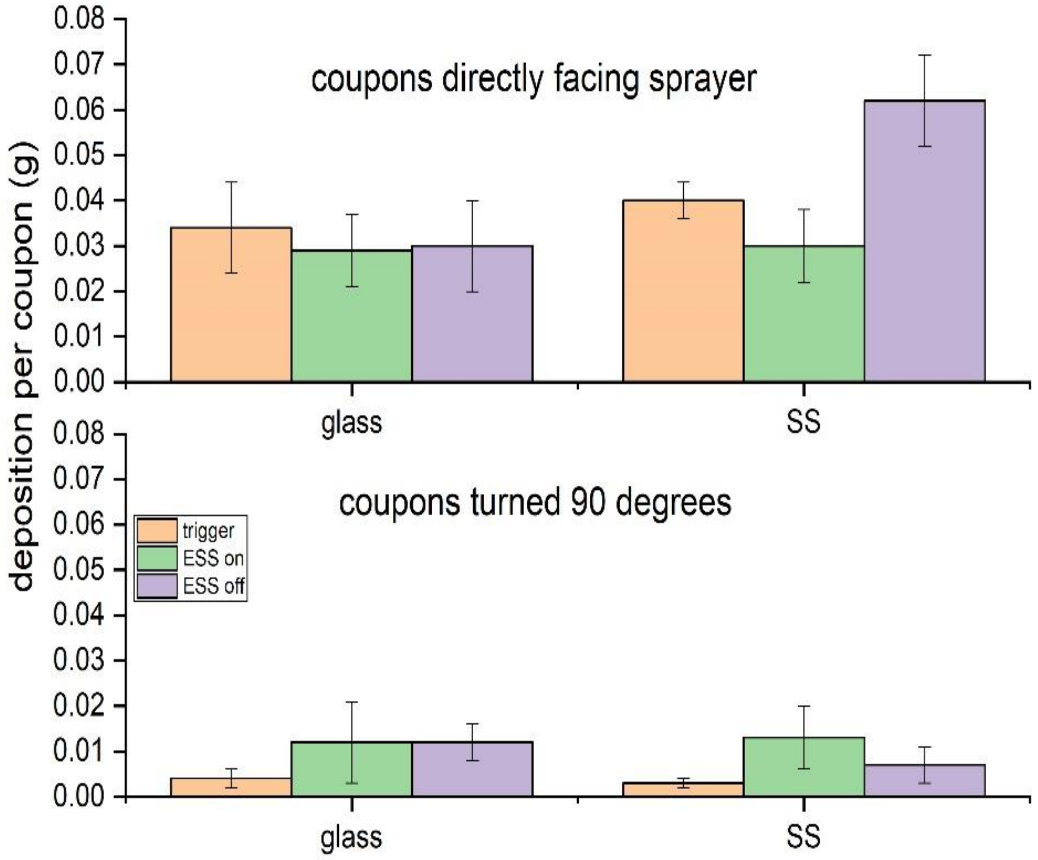
Disinfection efficacy test methods

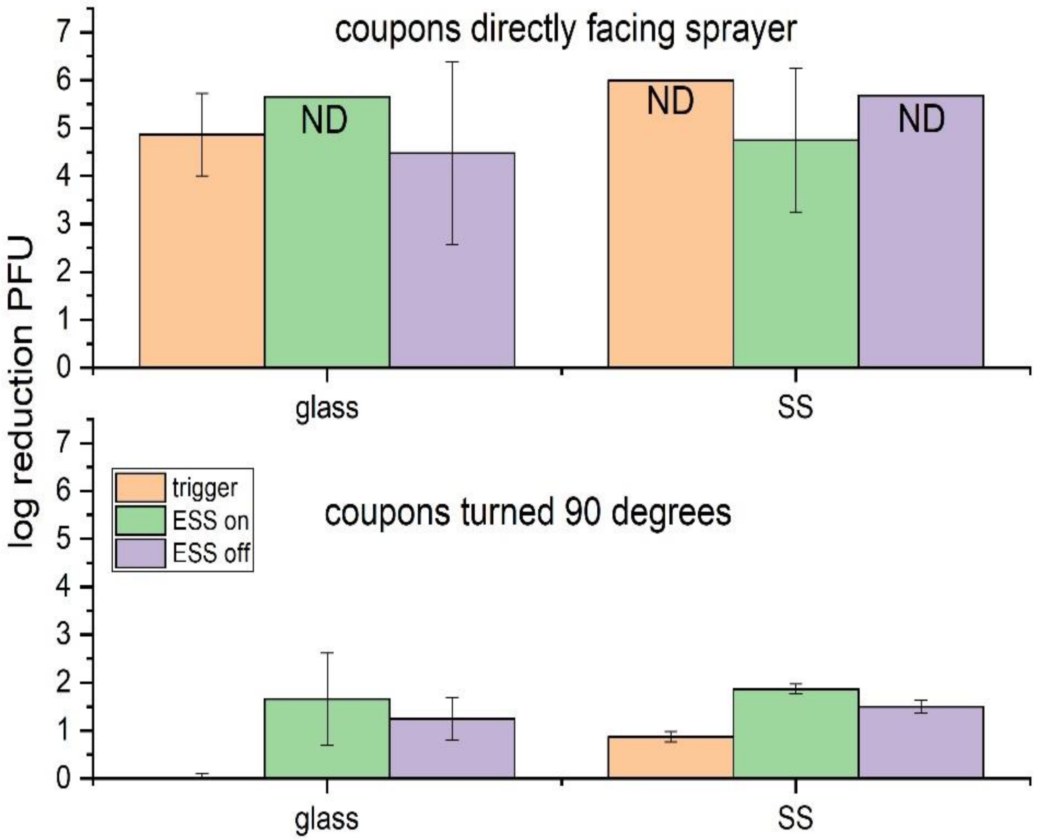
- Compared a trigger pull sprayer with an ESS
  - ESS tested with and without charging of spray
- Conducted deposition tests beforehand to ensure the mass of water deposited on coupons when facing forward was similar for the ESS and trigger sprayer
  - 2 trigger pulls at 1 ft or 2 sec spray from ESS HH resulted in about 0.03-0.04 gram/coupon

Disinfection efficacy test methods

- Coupons faced directly forward and turned 90 degrees
  - Glass and steel
- Used CDC dilute bleach recipe (1:50), 1 minute contact time (was about 2000 ppm FAC)
- Used Phi6 phage as surrogate for SARS-CoV-2
- 3 replicate coupons for each condition

Disinfection efficacy test results





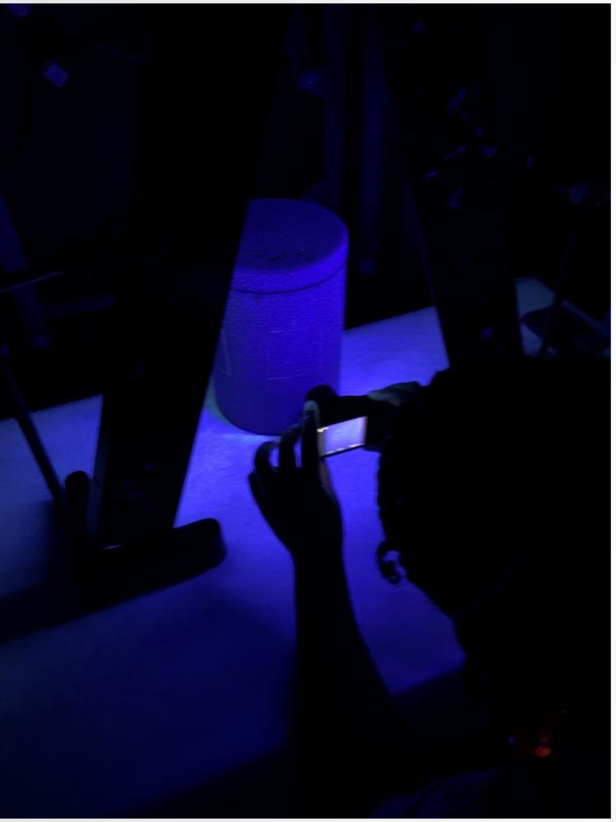
Disinfection efficacy test results

- The LR of virus correlated well with spray deposition on the coupons (R^2 =0.90)
  - Efficacy was much better w coupons directly facing sprayer, consistent with more spray deposited on coupons when facing that way
- For the coupons facing the sprayers, the efficacy and deposition results were not significantly different among the 3 sprayers, except maybe in one case (which may have been an outlier)
- For the coupons turned 90°, the electrostatic sprayer performed better than the trigger sprayer, by about 1-2 LR PFU – *regardless of whether the ESS was on or off.* Again, this was consistent with having more spray deposited
  - Minor, insignificant difference in efficacy for the ESS when the electrostatics were on or off
  - Reason for the higher deposition and thus higher efficacy compared to the trigger sprayer may be due to some other phenomenon, such as droplet size

Takeaways from ESS study

- Purpose of the study was to evaluate several different sprayers (ESS) and foggers for parameters related to their use for the application of disinfectants
- Multiple factors may affect deposition of spray on to a surface and thus may affect whether a surface can remain wet for the required contact time
- Disinfection efficacy was highly correlated to amount of disinfectant deposited on surface
- Most of the devices evaluated had a VMD ≥ 40 microns

Takeaways (continued)



- 4 out of 6 of the devices tested for charge produced sprays ≥ 0.1 mC/kg
- 2 out of 6 ESS produced sprays carrying a negative charge, while the other four carried a positive charge
- There was minimal apparent wrap-around effect of the spray deposition onto an 8-inch diameter cylindrical object, even for the ESS with the highest charge/mass
- The loss of AI to the air due to spraying the dichlor- and hydrogen peroxide-based disinfectants was minimal (below occupational health levels of concern)

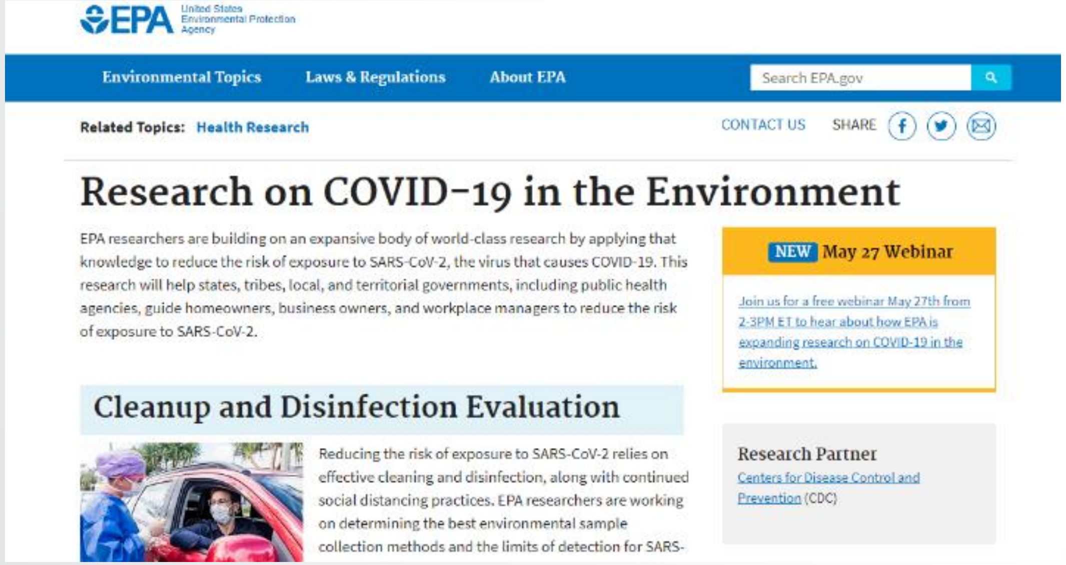
Further research

- Further investigate electrostatic charge of sprayers relative to:
  - Deposition and wrap around effect
  - Disinfection efficacy
  - Spray distance, flow rate
  - Chemistry
  - Spray and deposition uniformity
  - Measurement method

EPA COVID-19 Research Website

- More information is available at US EPA's CoV-2 Research website:

  https://www.epa.gov/covid19-research



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